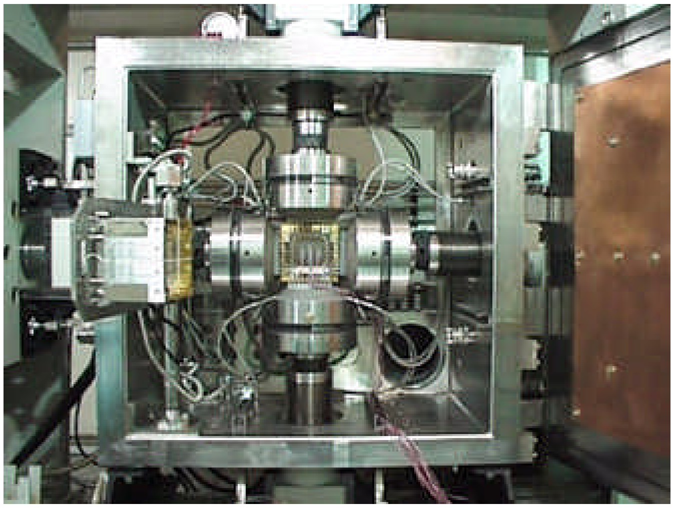
Strain Measurement System Developed for Biaxially Loaded Cruciform Specimens

Components of mechanical equipment under load are routinely subjected to multiaxial states of stress at elevated temperatures. In addition, many construction materials exhibit anisotropic properties. For these conditions, in-plane biaxial testing of cruciform (cross-shaped) specimens is important for deriving mechanical properties used in design and life prediction.

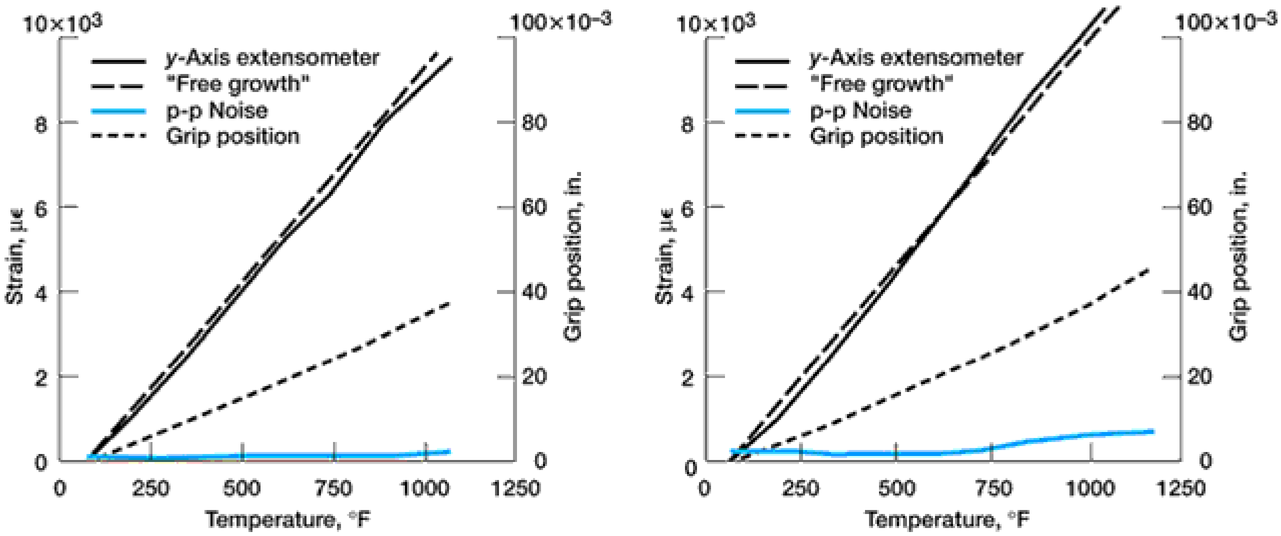
Accurate strain measurement during biaxial testing is critical. It permits calculating specimen test area stresses under various loading conditions. Real-time measurement permits observation of deformation behavior under biaxial loading conditions. In addition, continuous electronic measurement is used in the closed-loop test control for strain-controlled experiments and in all test types for sensing test-termination strain limits.



In-plane biaxial load frame with cruciform specimen.

A new extensometer system developed at the NASA Glenn Research Center at Lewis Field measures test area strains along two orthogonal axes in flat cruciform specimens. This system incorporates standard axial contact extensometers to provide a cost-effective high-precision instrument. The device was validated for use by extensive testing of a stainless steel specimen, with specimen temperatures ranging from room temperature to 1100 °F. In-plane loading conditions included several static biaxial load ratios, plus cyclic loadings of various waveform shapes, frequencies, magnitudes, and durations. The extensometer system measurements were compared with strain gauge data at room temperature and with calculated strain values for elevated-temperature measurements. All testing was performed in house in Glenn’s Benchmark Test Facility in-plane biaxial load frame.

A summary of the verification testing results follows: (1) the new extensometer system was calibrated with a maximum error of 0.8 percent; (2) the room-temperature correlation with strain gauge data yielded an average variation of 58 microstrain; (3) operation under cyclic conditions resulted in tracking errors of less than 3 percent; (4) elevated-temperature results compared accurately with theoretical predictions; and (5) long-duration testing proved to be stable.



Extensometer operation for free thermal growth of AISI Type 304 specimen. Left: x-direction. Right: y-direction.

This strain measurement system was developed to test advanced materials for the Advanced High Temperature Engine Materials Analysis Program (HITEMP) and the High-Speed Civil Transport propulsion system (HSR/EPM). The candidate materials would be used in turbine engine components that are under highly multiaxial states of stress. Although monolithic, the mechanical properties of these cast materials exhibit directionality because of large grain sizes. The extensometer system could be used for the future testing of other high-temperature materials, including polymer and ceramic matrix composite materials.

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